

## First Warm Dense Matter School at LBNL

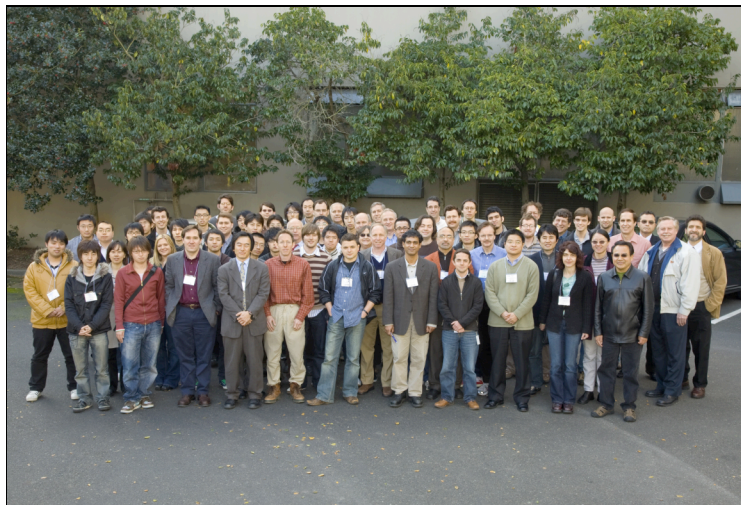


Figure 1. WDM school photo taken on 01/14/2008 at LBNL, Berkeley, CA.

During the week of January 10 - 16, 2008, the Heavy Ion Fusion Science Virtual National Laboratory cosponsored the 2008 Warm Dense Matter Winter School. The school was very well attended with 92 registrants (see school photo on Figure 1) from the United States (46), Japan (25), China (6), Canada (4), Russia (3), Germany (2), South Korea (2), Romania (2), France (1) and Israel (1). The school provided students and researchers introductions to the physics of Warm Dense Matter from both theoretical and experimental perspectives.

Richard More provided morning lectures on each of the five days outlining how the Warm Dense Matter regime may be approached as an extreme limit of four different regimes in the temperature-density parameter space: (1) "hot" solid or liquid matter; (2) "cool" plasma physics; (3) "dense" chemical reactions; or (4) "low density" limit of super-dense (shocked) matter. He emphasized that because key dimensionless numbers are of order unity, the WDM regime may nonetheless have unique properties that are more than just a simple interpolation between the four regimes and that there are thus "mysteries to be sorted out". Other talks described how WDM can be created experimentally using ion beams, laser beams, pulsed wires, x-ray FEL's, and other methods. Hitoki Yoneda provided three morning lectures on laser experiments in WDM and highlighted the role polarization measurements can have in diagnosing WDM. In Jonathan Wurtele's perspectives on the school, he outlined some of the questions addressed at the school, including: "what defines the WDM regime?", "how is it studied theoretically?", and "what are the applications?". For theoretical studies, he gave examples taken from hydrodynamics, quantum-molecular dynamics, equation of state and transport property calculations, and presented various computer codes that have been developed to simulate material in the WDM regime. A number of applications were discussed including planetary and stellar interiors, high temperature and high current switches, pulsed power technology, laser machining, and inertial-fusion chamber dynamics.

The school was sponsored by the Heavy Ion Fusion Science Virtual National Laboratory, the University of California's Institute for

Material Dynamics at Extreme Conditions (IMDEC), and the Japanese JSPS Core-to-Core Program "International Collaboration for High Energy Density Science." The agenda for the school and most of the talks may be found on the web at: <http://hifweb.lbl.gov/wdmschool>.

- John Barnard

### Charge and Current Neutralization of an Ion Beam Pulse Propagating in a Background Plasma along a Solenoidal Magnetic Field

The application of a small solenoidal magnetic field can drastically change the self-magnetic and self-electric fields of the beam pulse, thus allowing effective control of the beam transport through the background plasma. An analytical model is developed to describe the self-magnetic field of a finite-length ion beam pulse propagating in a cold background plasma in a solenoidal magnetic field [1]. The analytical studies show that the solenoidal magnetic field starts to influence the self-electric and self-magnetic fields when  $\omega_{ce} > \omega_{ep} \beta_b$ , where  $\omega_{ce} = eB/mc$  is the electron gyro-frequency,  $\omega_{ep}$  is the electron plasma frequency, and  $\beta_b$  is the ion beam velocity relative to the speed of light. Theory predicts that when  $\omega_{ce} \omega_{ep} \rho_b$  there is a sizable enhancement of the self-electric and self-magnetic fields due to the dynamo effect. This threshold value of solenoidal magnetic field is relatively small for non-relativistic beams. The dynamo effect occurs due to the electron rotation, which twists the applied magnetic field and generates a self-magnetic field that is much larger than in the limit with no applied magnetic field.

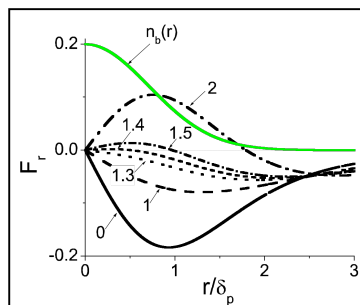


Figure 2. The normalized radial force acting on the beam particles for different values of the parameter  $(\omega_{ce}/\omega_{ep}\beta_b)^2$ . The green line shows the Gaussian density profile multiplied by 0.2 in order to fit the profile into the plot. The beam radius is equal to the skin depth.

The second effect is the generation of a large radial electric field. Because in a steady state the  $v \times B$  force should be balanced by a radial electric field, the electron rotation results in a plasma polarization and produces a much larger self-electric field than in the limit with no applied field. The third unexpected effect is that the joint system consisting of the ion beam pulse and the background plasma act as a paramagnetic medium, i.e., the solenoidal magnetic field is enhanced inside of the ion beam pulse. For larger values of the solenoidal magnetic field, corresponding to the beam generates whistler and lower-hybrid waves. In the presence of the solenoidal magnetic field, the radial force acting on the beam ions can change sign from focusing to defocusing, because the radial electric field increases more rapidly than the magnetic force, as the solenoidal magnetic field increases, as shown in Figure 2.

- I.D. Kaganovich, E. A. Startsev, A. B. Sefkow, R. C. Davidson  
PPPL, Princeton University, Princeton, NJ

[1] I.D. Kaganovich et al., *Phys. Rev. Lett.* **99**, 235002 (2007)

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